Site Characterization for CO_2 Storage from Coal-Fired Power Facilities in the Black Warrior Basin of Alabama

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Mason Tomson, Rice University

DE-FE0001910

PROJECT TEAM

- ✓University of Alabama (Lead)
- ✓Geological Survey of Alabama
- ✓Rice University

- ✓Southern Company, Alabama Power
- ✓Schlumberger Carbon Services
- ✓Micro-g Lacoste
- ✓Halliburton/Pinnacle Technologies
- ✓SECARB
- ✓University of Alabama at Birmingham

DURATION AND BUDGET

- ✓ Performance Period
  - December 8, 2009 to December 7, 2012
  - Divided into three equal budget periods

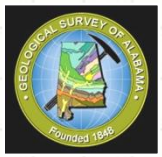
- ✓ Budget
  - Total project cost — $17,410,794
  - Government share — $9,849,924
  - Cost share — $7,560,870

PROJECT GOALS

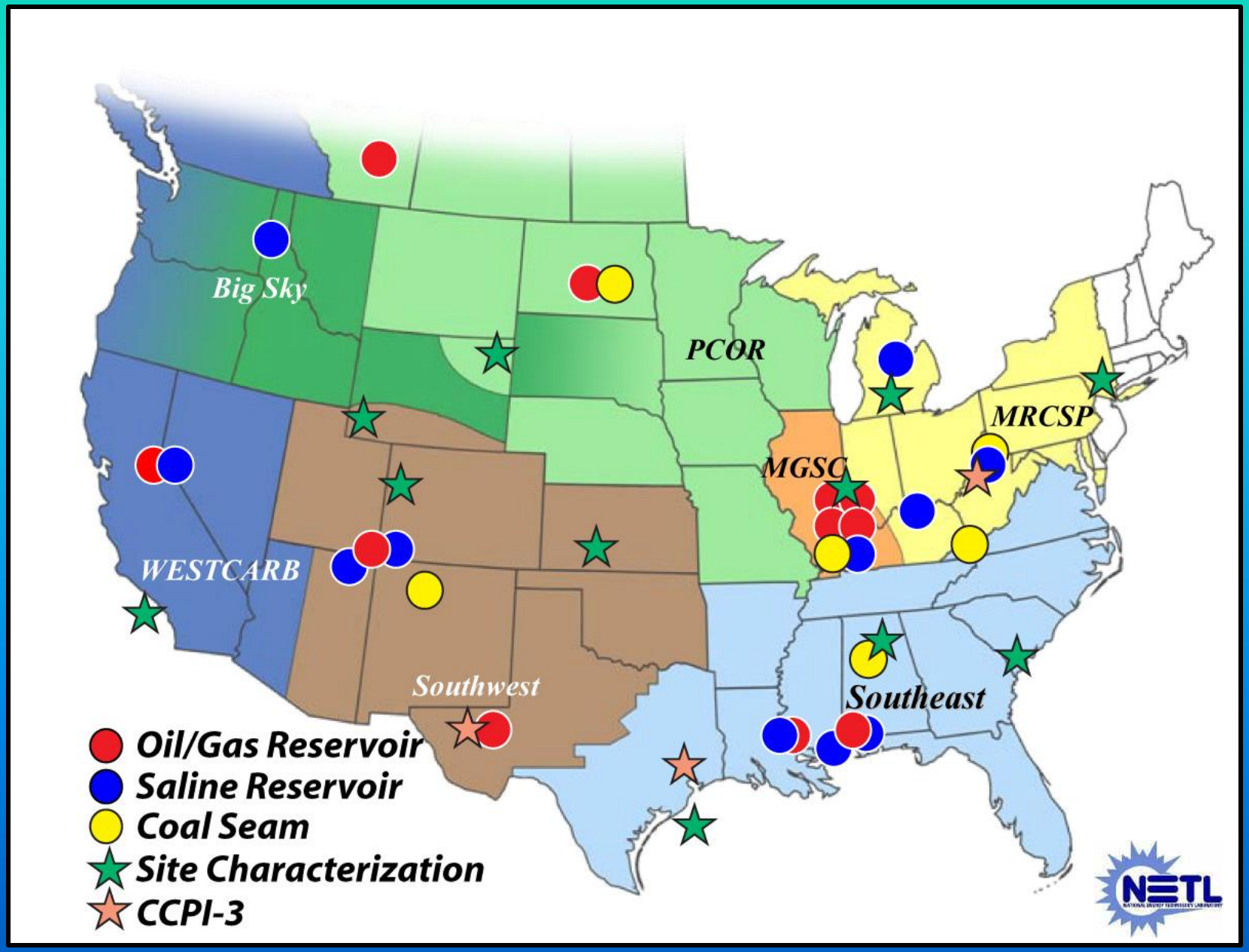
- Analyze the CO_2 storage capacity and injectivity of stacked saline formations in the Cambrian-Pennsylvanian section of the Black Warrior basin.
- Assess the risks associated with geologic carbon storage in the Black Warrior basin.
- Develop a regional plan and BPM for carbon sequestration.

PROJECT OBJECTIVES

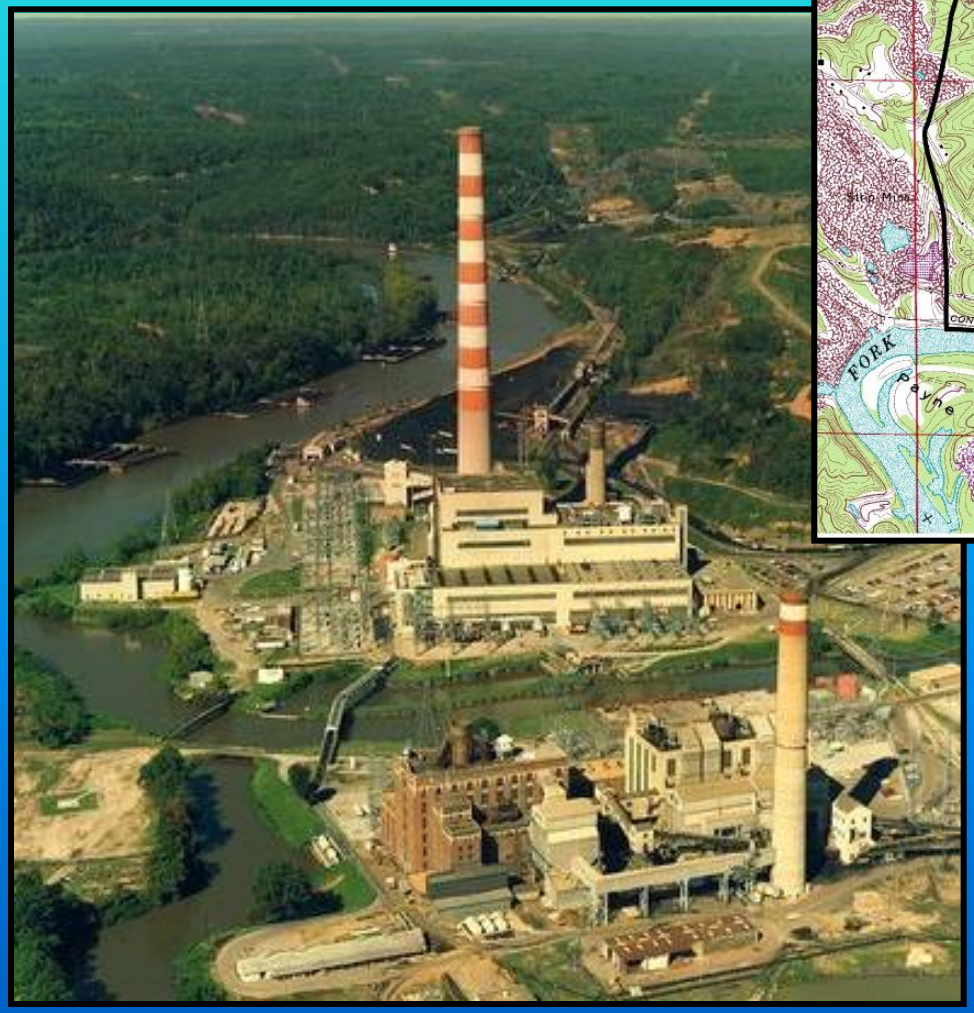
- ✓Assess saline reservoirs, O&G reservoirs
- ✓Shoot 2-D seismic profiles
- ✓Drill 8000-ft well at Plant Gorgas
- ✓Core reservoirs and seals
- ✓Quantify reservoir properties using
  - Advanced petrophysical and geophysical techniques
  - Injection/well testing
  - Integrity testing using mini-fracs
- ✓Analysis of mineralization, dissolution, seals
- ✓Reservoir simulation
- ✓Develop best practices manual
- ✓Leave infrastructure at plant

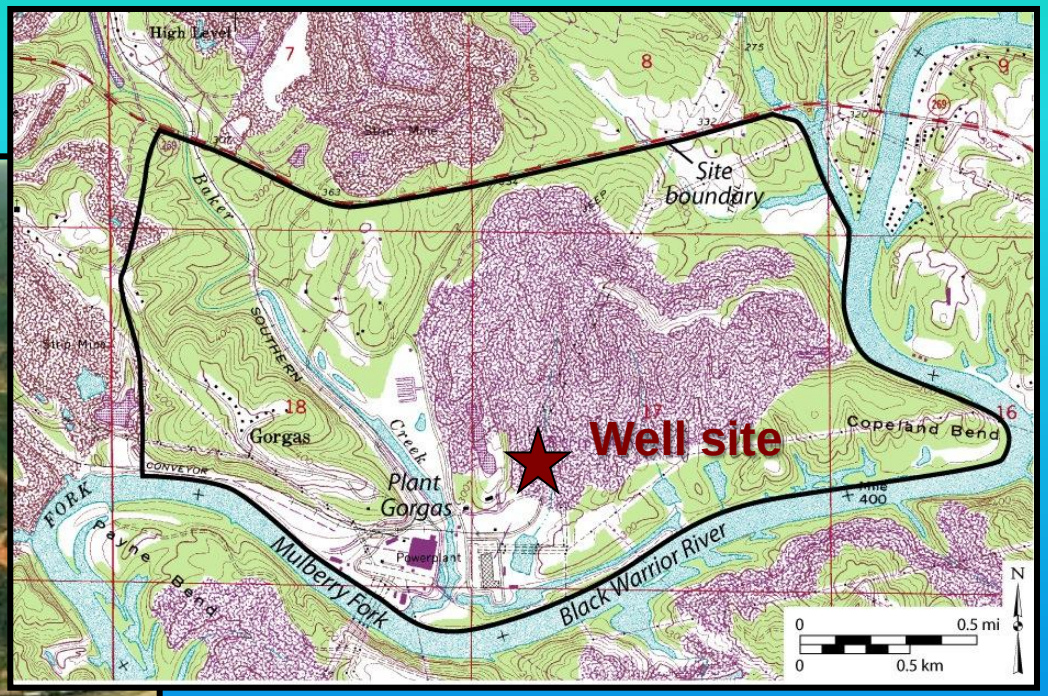


REGIONAL PARTNERSHIPS



WILLIAM CRAWFORD GORGAS STEAM PLANT





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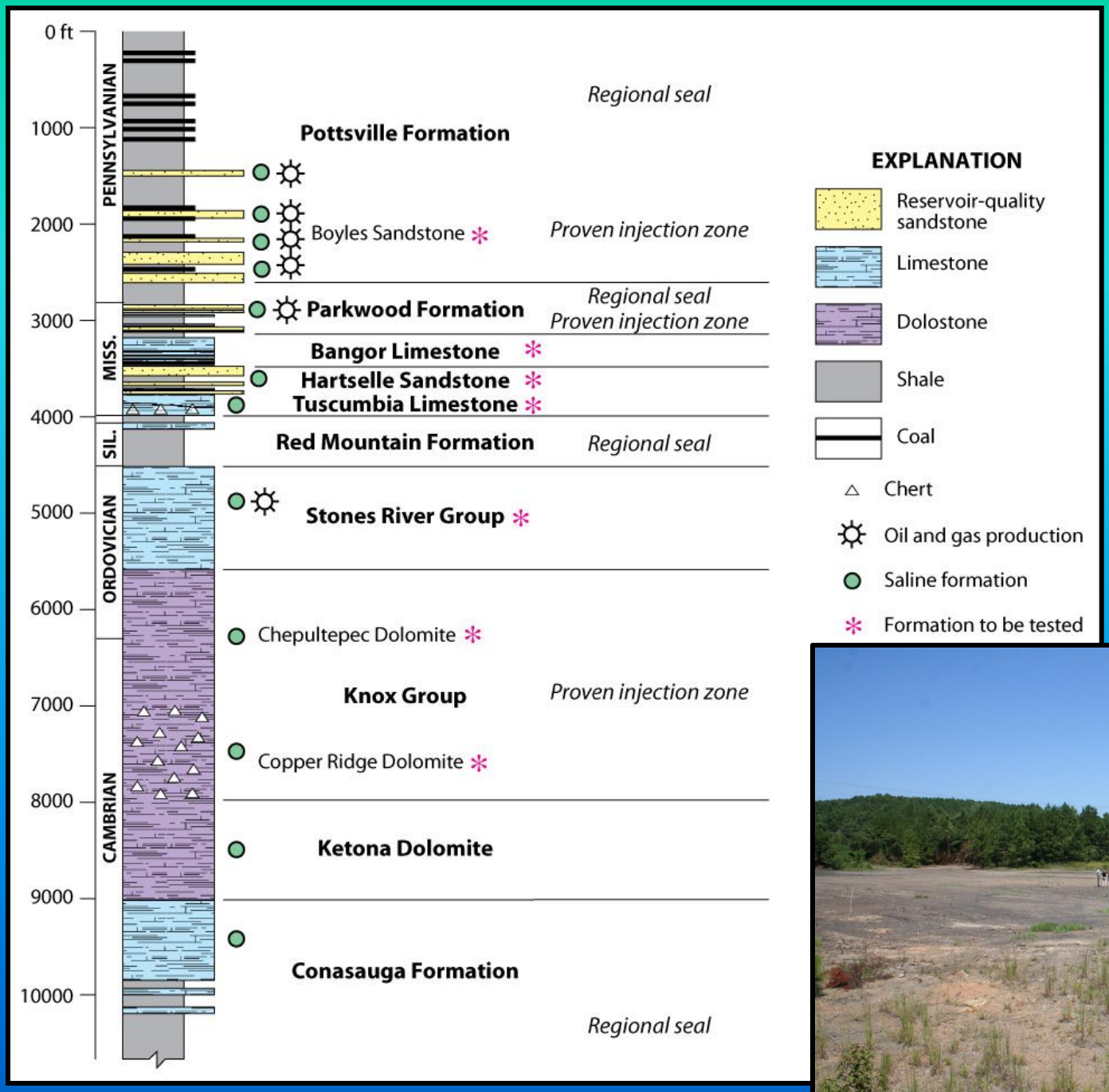
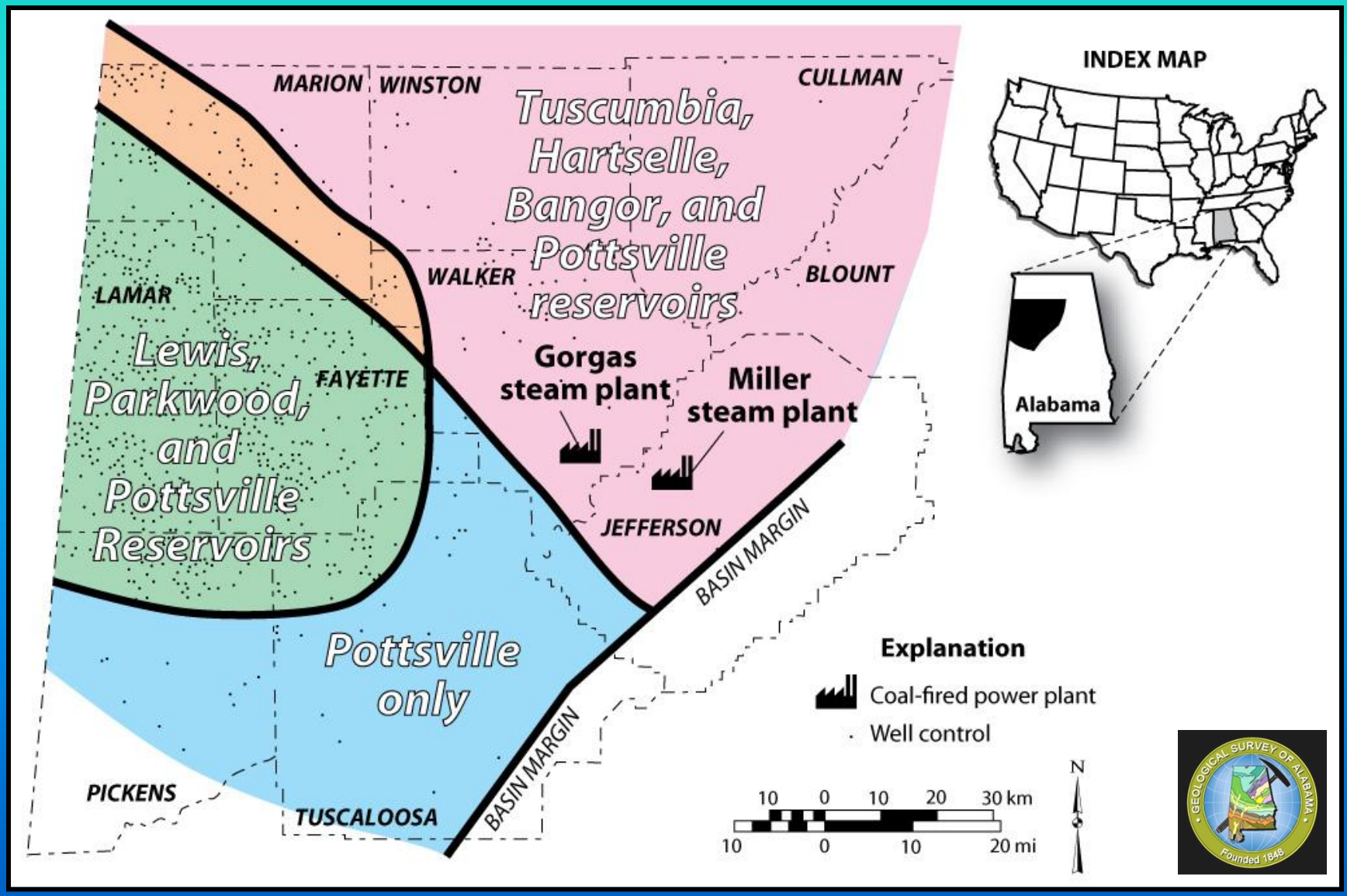
BLACK WARRIOR BASIN

Storage opportunities



CHARACTERIZATION AREA, BLACK WARRIOR BASIN



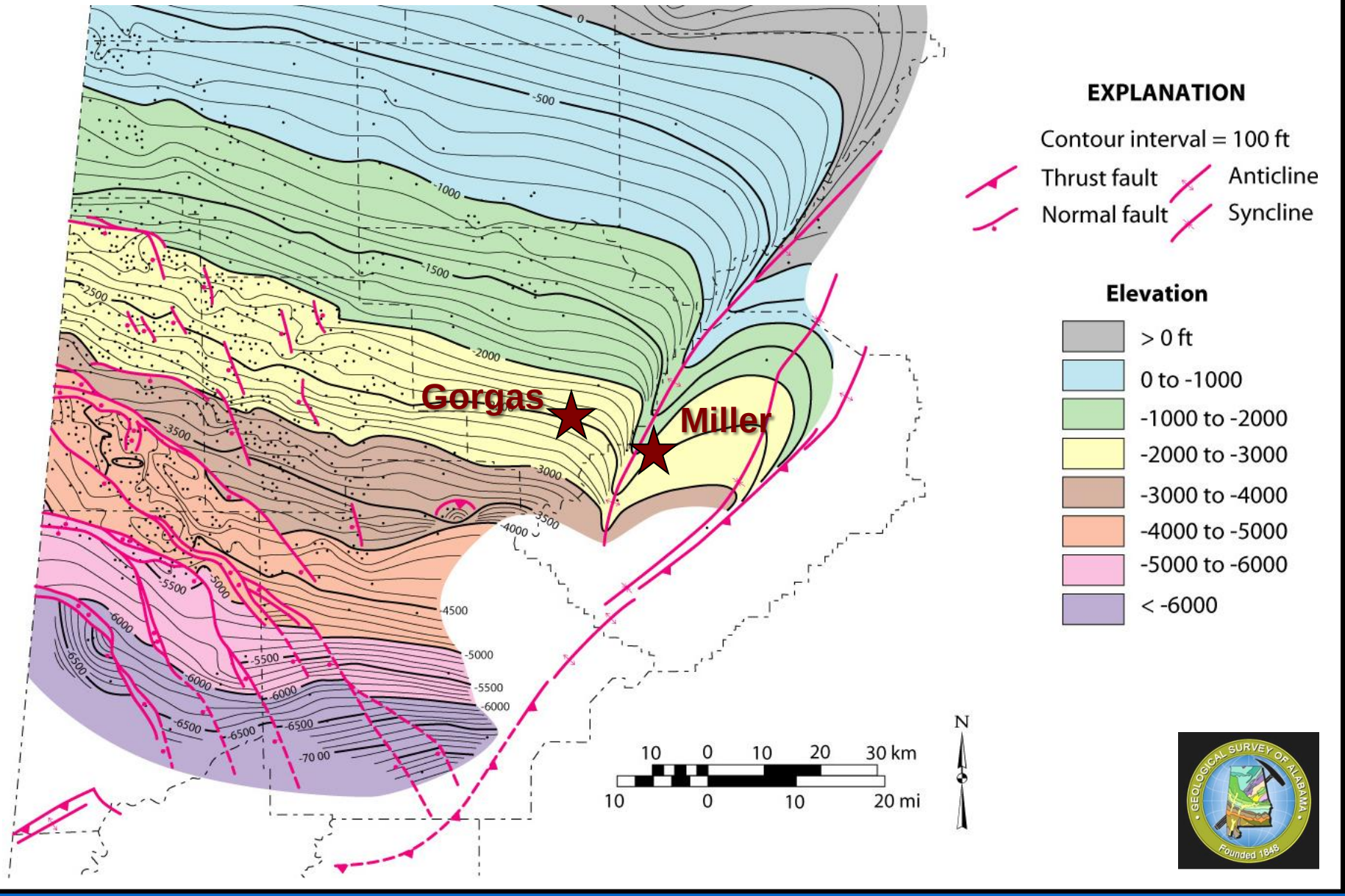
PRELIMINARY CAPACITY ESTIMATE

Formation	Areal extent (mi^2)	Net Pay (ft)	Porosity (%)	Capacity (tonnes/mi^2)	Regional capacity (gigatonnes)
Pottsville Formation**	9,400	260	18	2,031,969	19.1
Parkwood Formation	2,820	48	15	312,611	0.9
Bangor Limestone*	5,640	50	15	325,636	1.8
Hartselle Sandstone*	5,640	72	15	468,916	2.6
Lewis Sandstone	2,820	27	15	175,844	0.5
Tuscumbia Limestone*	5,640	90	15	586,145	3.3
Total				**3,901,121**	**28.2**

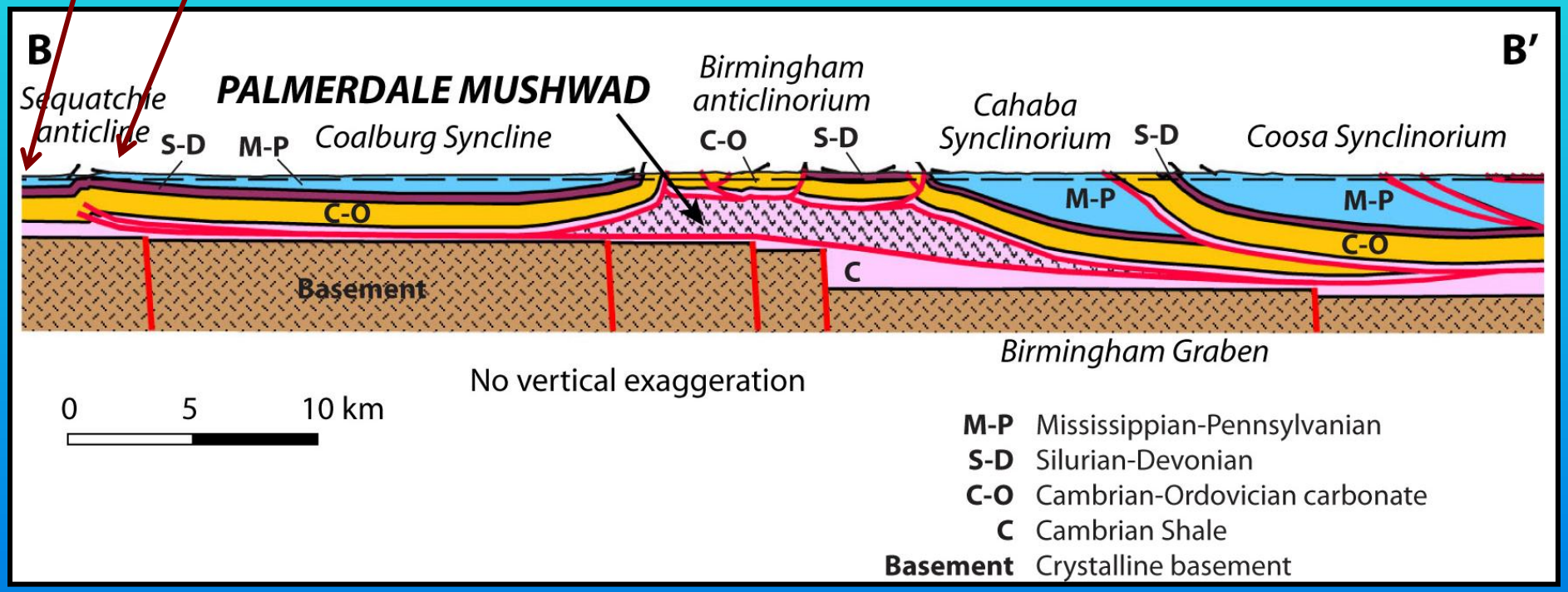
* Saline formation present at test site

** Shallower than 2,480 feet at test site.

TUSCUMBIA STRUCTURE

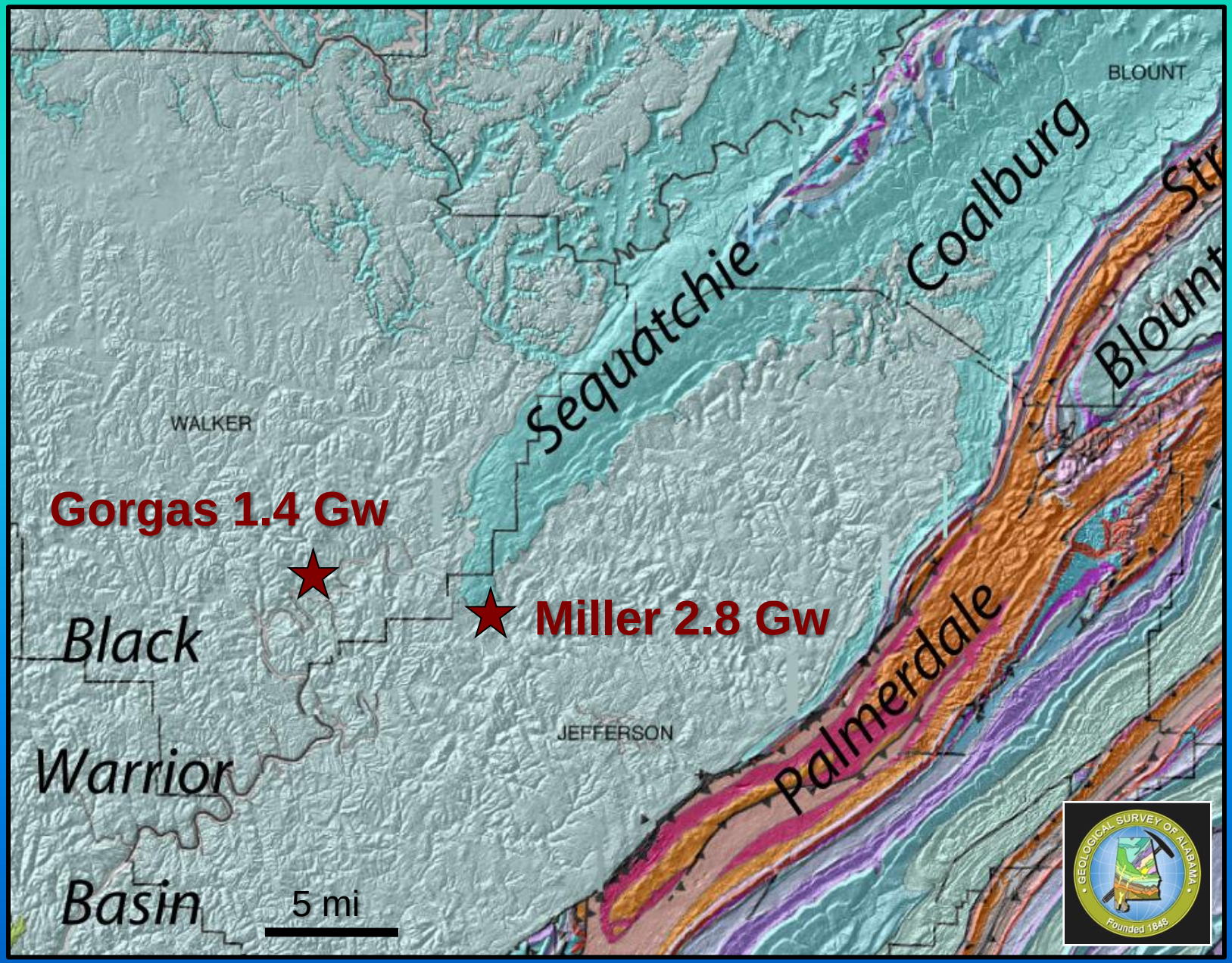


APPALACHIAN STRUCTURE

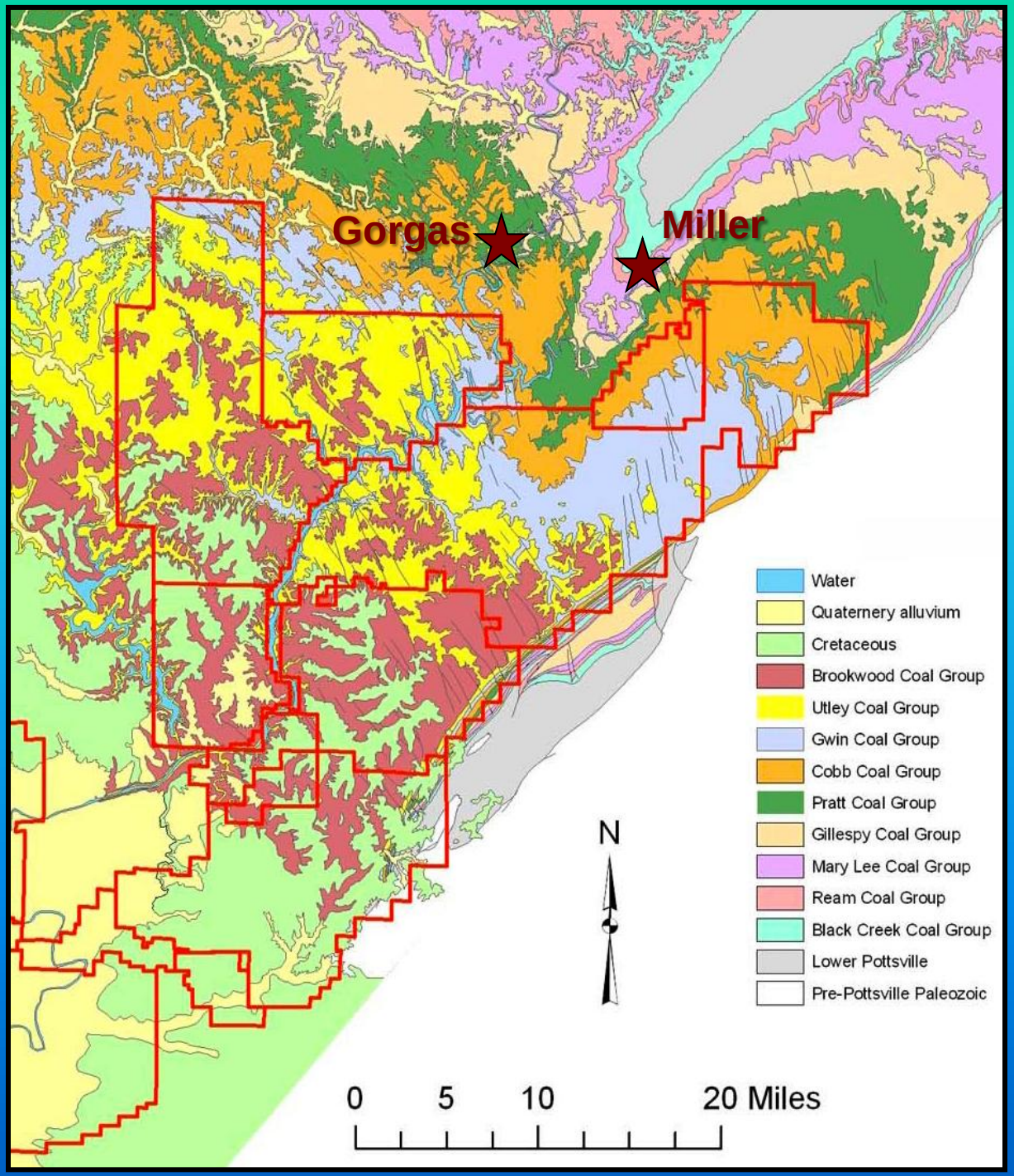


Thomas and Bayona (2005)

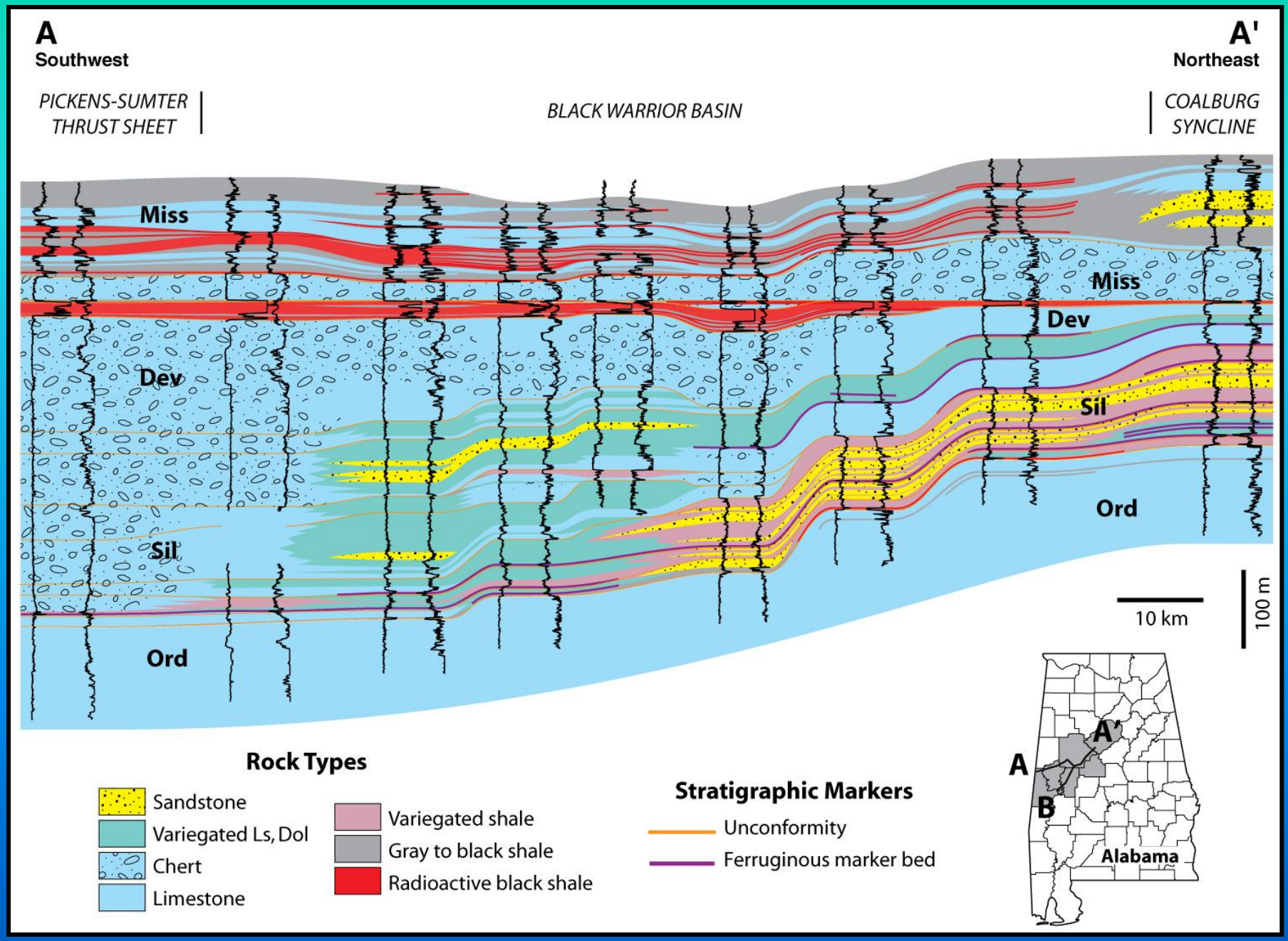
GEOLOGIC MAP



SURFACE GEOLOGY



DEVONIAN-MISSISSIPPIAN SHALE

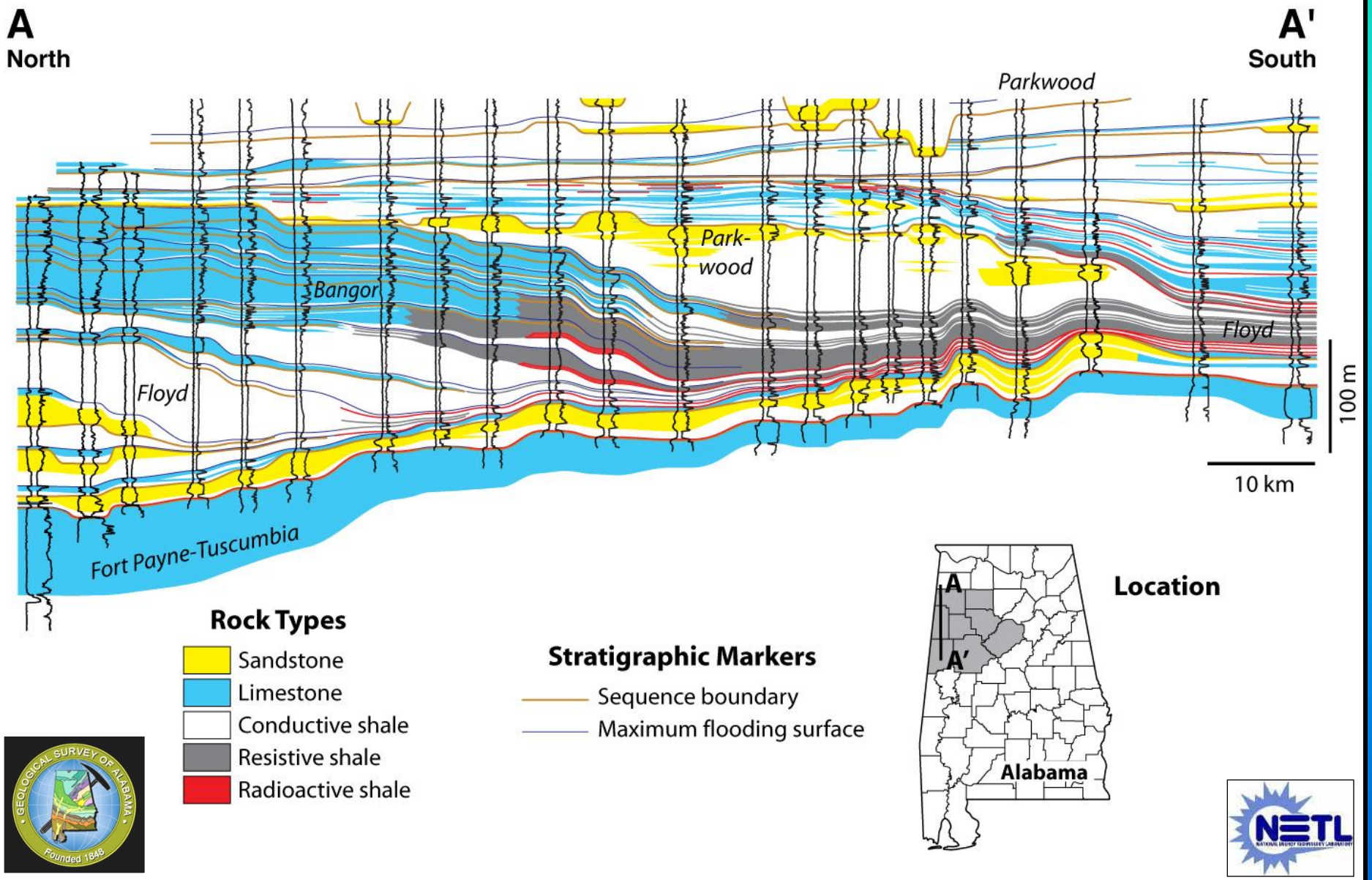


CARBONIFEROUS SANDSTONE

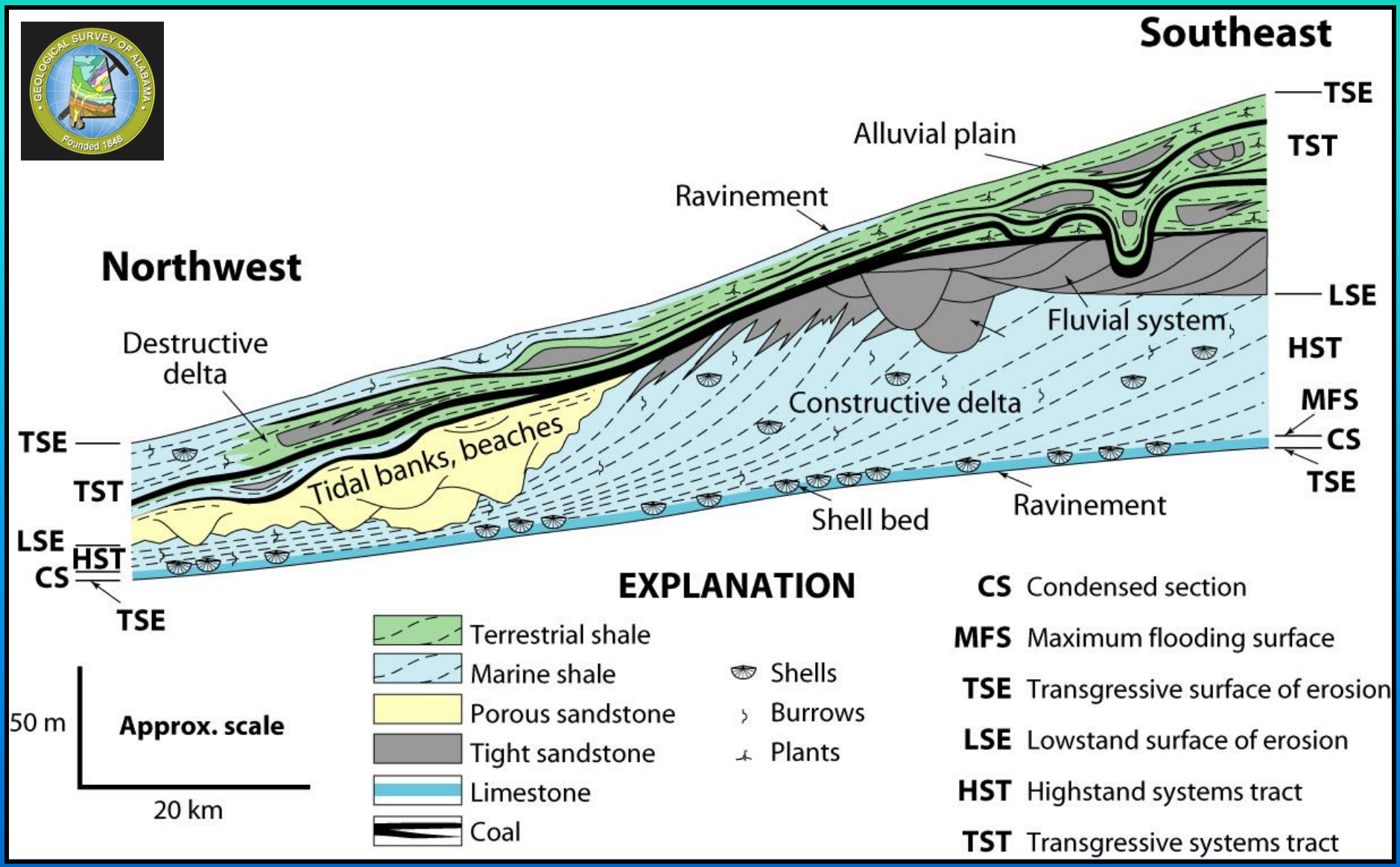
Tangential cross-bedding

Wedge-planar cross-bedding

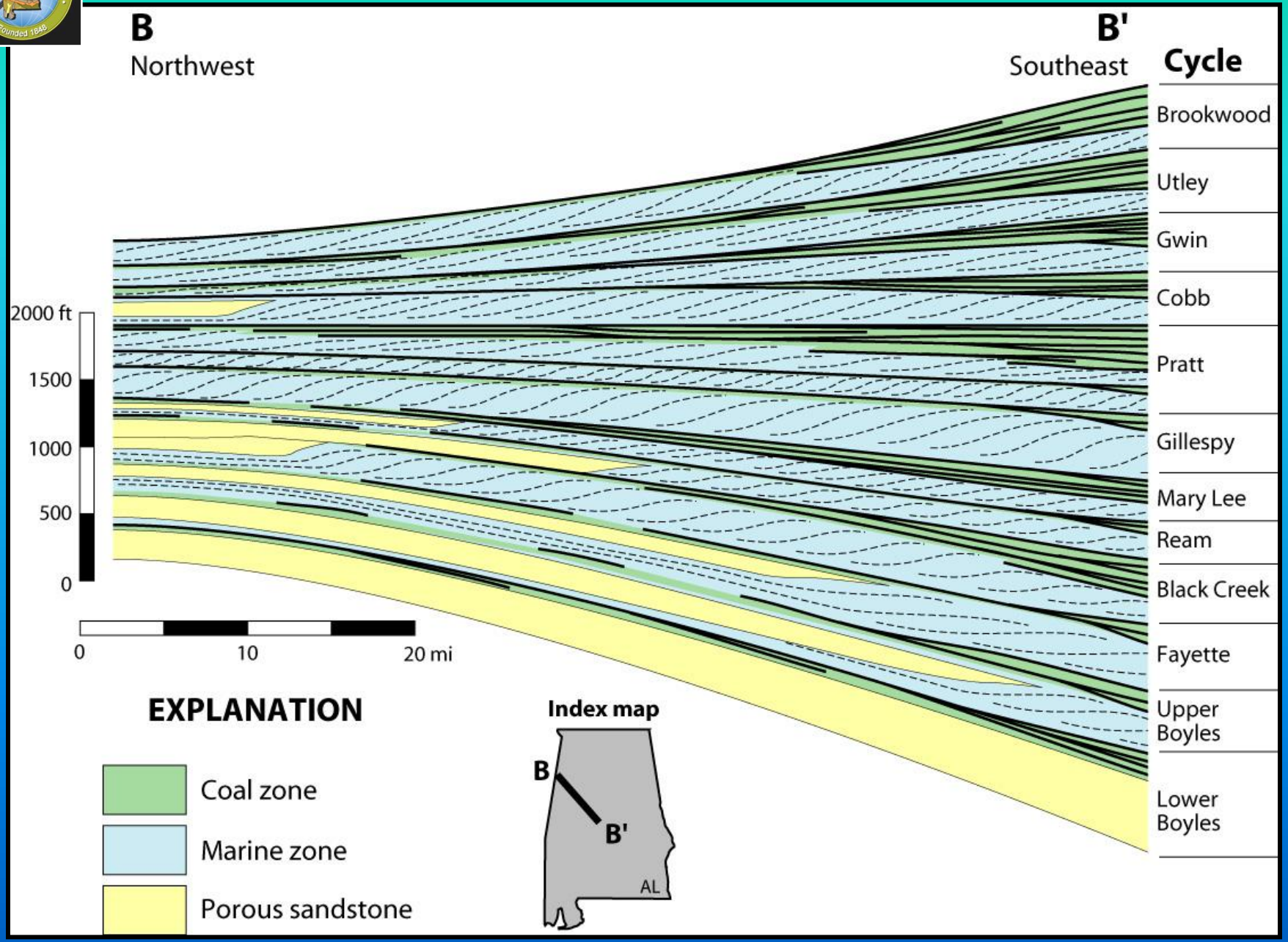
MISSISSIPPIAN STRATIGRAPHY



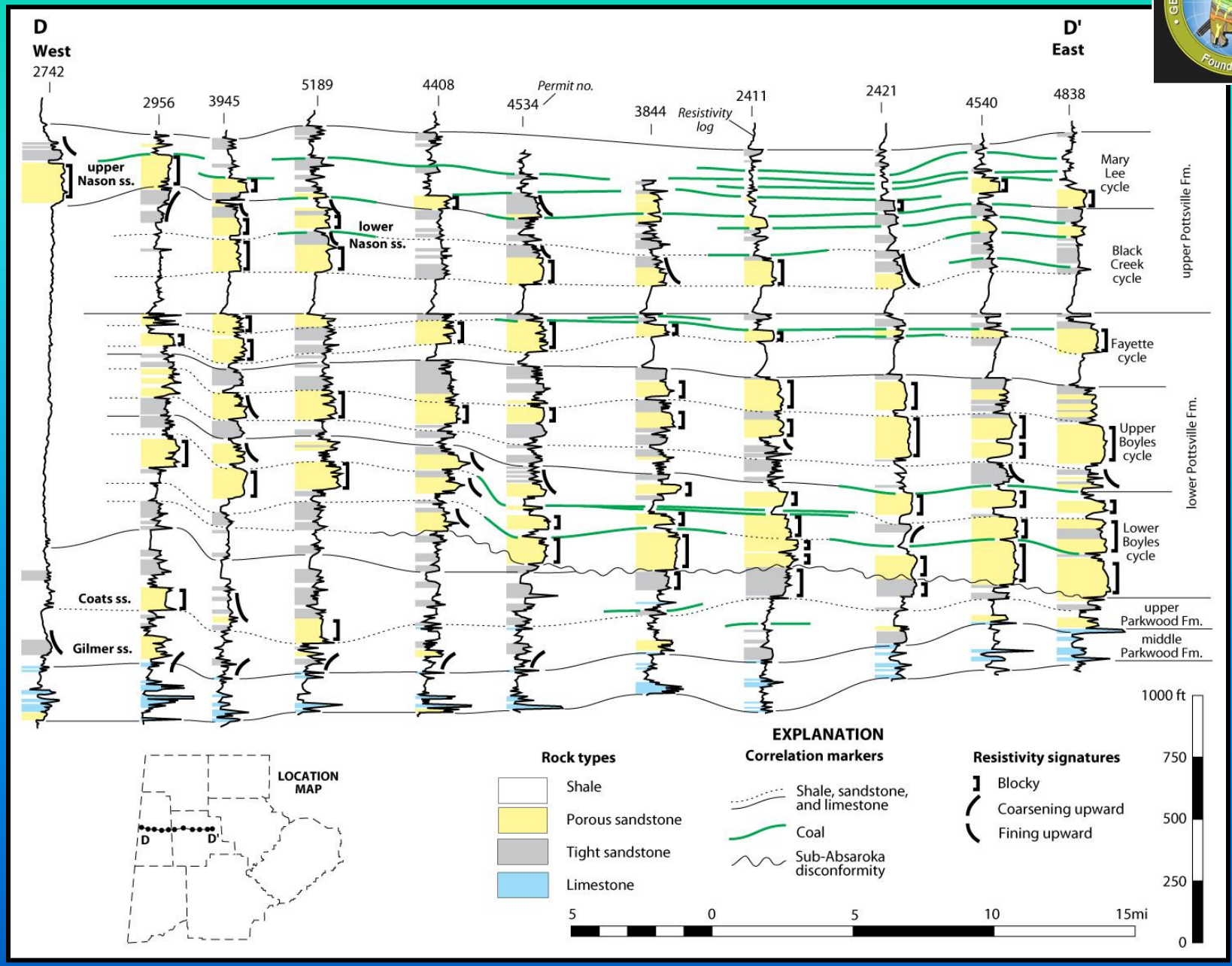
IDEALIZED POTTSVILLE CYCLOTHEM



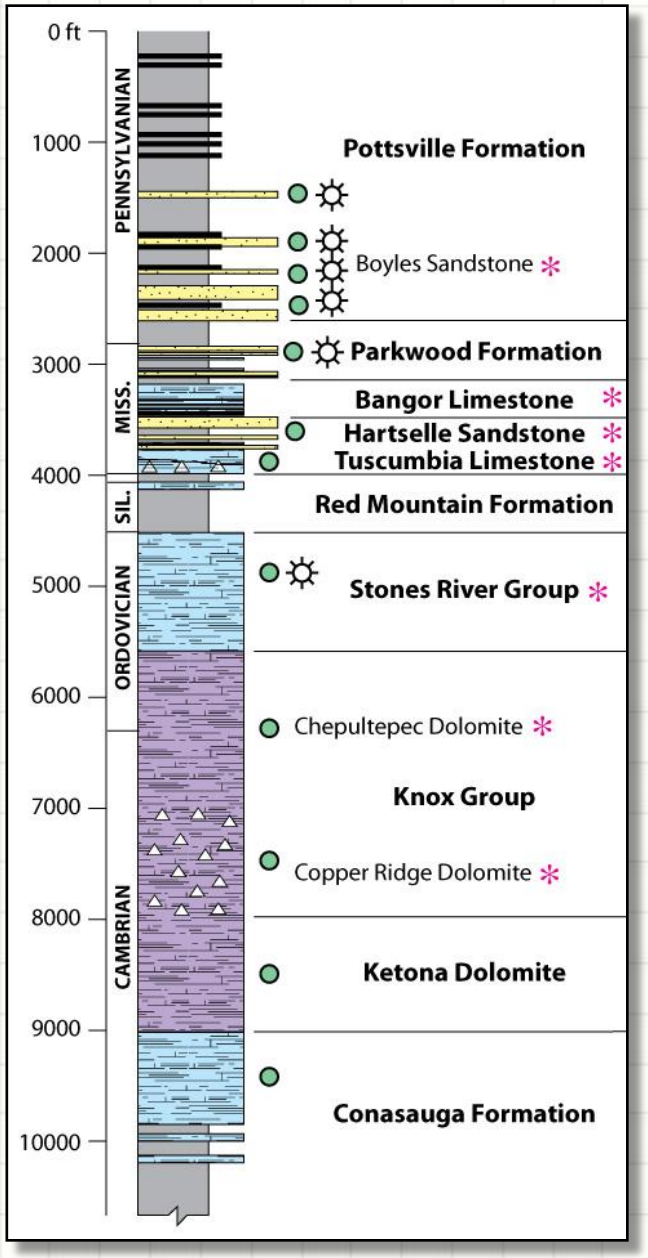
REGIONAL STRATIGRAPHY



REGIONAL STRATIGRAPHY



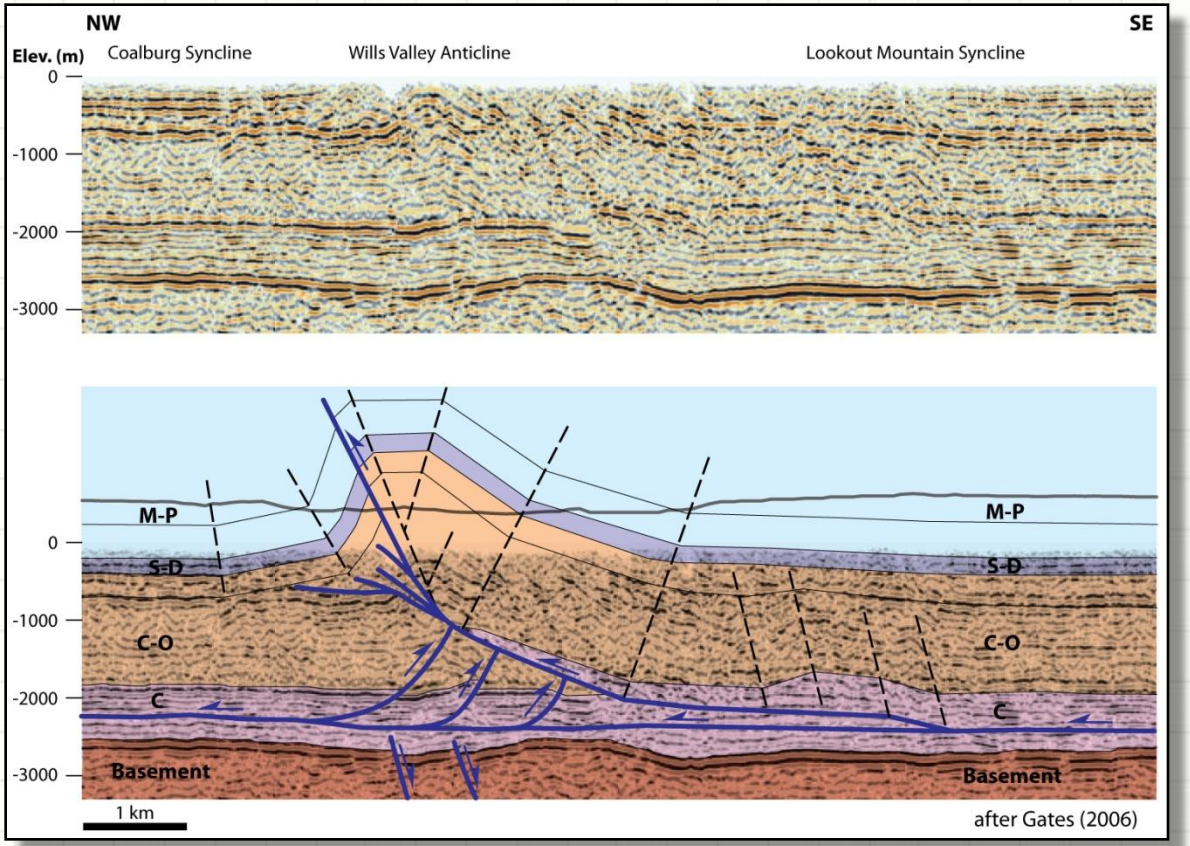
EXPLORATORY WELL



- ✓ Depth ~8000 ft (TD est. in Cambrian Dolomite)
- ✓ Extensive log suite
- ✓ Multiple coring points (full core and sidewall)
- ✓ Conventional core analysis
- ✓ Tight-rock analysis
- ✓ Geophysical testing (VSP, microseismic, borehole gravity)
- ✓ Injectivity testing
- ✓ Mini-frac testing

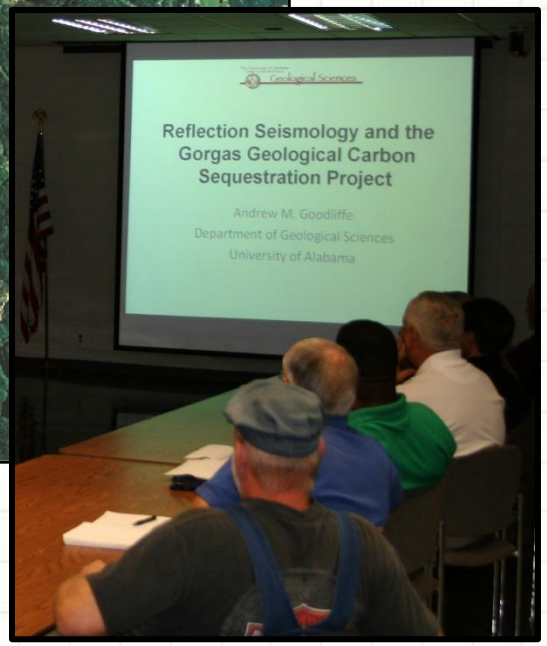
SEISMIC REFLECTION

- 10 miles of seismic reflection along County and State Highways
- Two perpendicular lines configured to image regional structure
  - Appalachian folds
  - Thin-skinned normal faults



SEISMIC REFLECTION

- ✓ Nominal 10 foot receiver interval
- ✓ 40 foot group interval (variable)
- ✓ 120 foot source interval
- ✓ 3 Hemi-44 truck mounted vibrators
- ✓ Max offset along a 5 mile line of 24,600 foot
- ✓ Processing though depth migration
- ✓ Inversion with well data
- ✓ Amplitude versus offset analysis
- ✓ Detailed attribute analysis



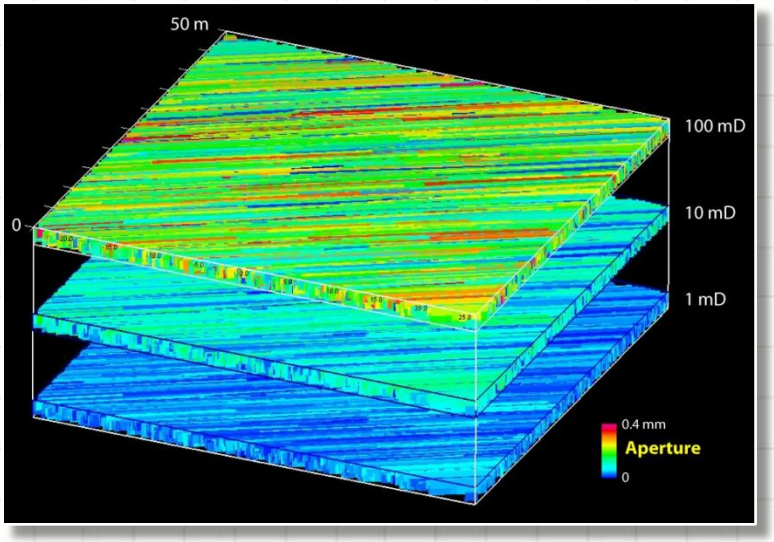
SEISMIC TOMOGRAPHY

- 100-200 “Texan” single channel geophones deployed during Vibroseis survey
- Data will be used to build a regional velocity model
- Extends seismic results to 3-D (though at lower resolution)
- Important for constraining reservoir models beyond seismic reflection coverage
- Potential for additional seismic anisotropy data

ADDITIONAL GEOPHYSICS

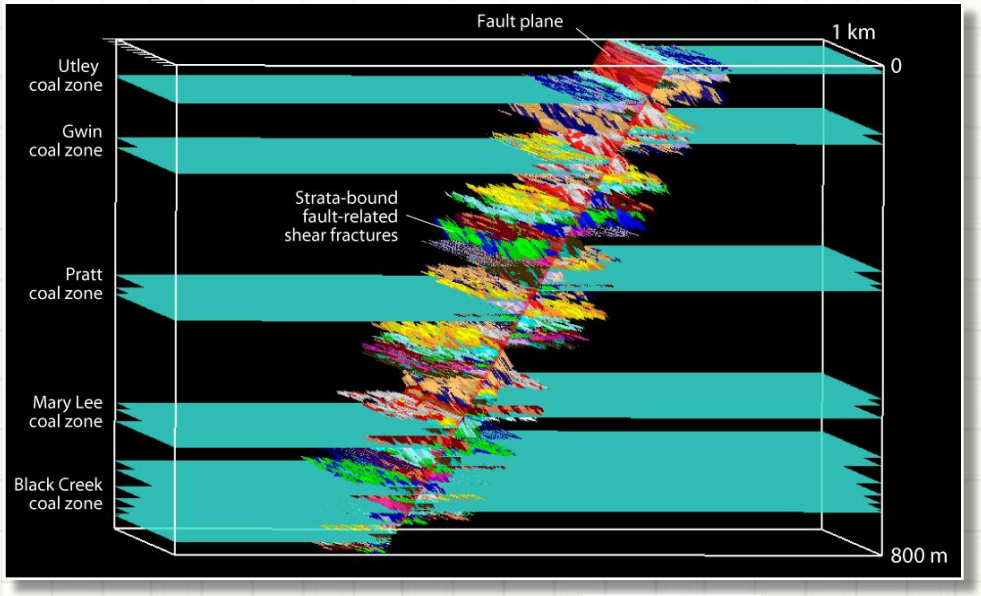
- ✓ Multi-offset VSP
  - Correlation of well and seismic data
  - Depth conversion
  - Identify multiples in conventional seismic data
- ✓ Synthetics
- ✓ Borehole gravity
  - Density, porosity and heterogeneity away from the borehole
- ✓ Microseismic monitoring during water injection
  - Little seismicity expected
  - Constrain regional stress state and fracture direction and compare results with other methods
  - Identify potential cross-formational flow

RESERVOIR SIMULATION



- ✓ Integrate continuum and discrete reservoir elements
- ✓ Attempt to identify characteristics (beyond porosity and permeability) that appear to have substantial impact on CO_2 sequestration

- ✓ Assess storage capacity
- ✓ Estimate CO_2 injection rates
- ✓ Assess long-term viability of storage



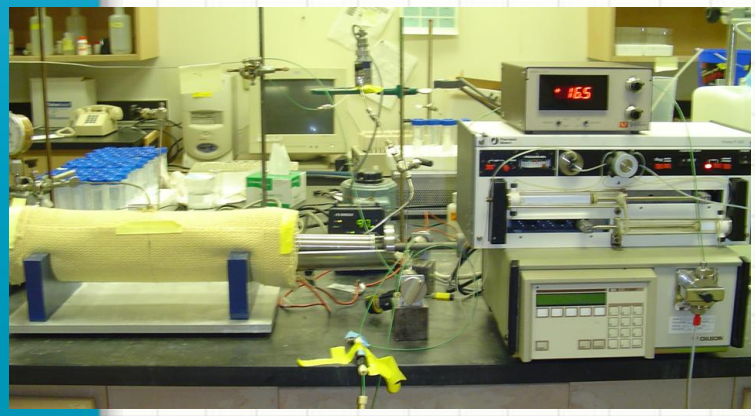
RESERVOIR SIMULATION

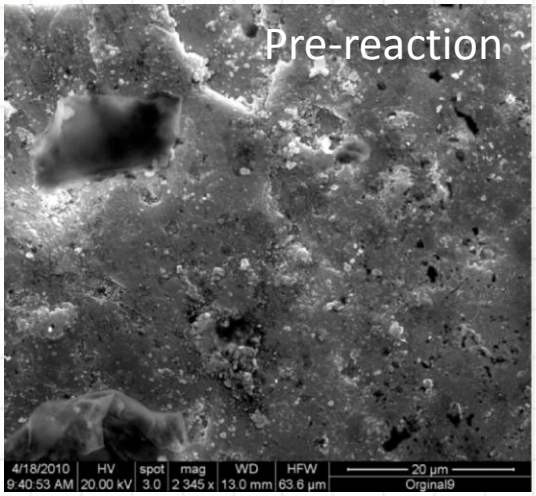
- The assessment of geochemical issues requires investigation at pore scale
- Determining long-term viability requires basin-scale calculations
- Simulator must be able to handle large numbers of cells (> 10^6) with many unknowns per cell
- The simulation team has developed a very flexible simulator and visualization framework
- The framework required the slight modification of a petroleum industry standard equation-of-state formulation
- BSD-style license, so anyone can use or modify the code
- Code base utilizes cutting-edge hardware; e.g., GPU cards

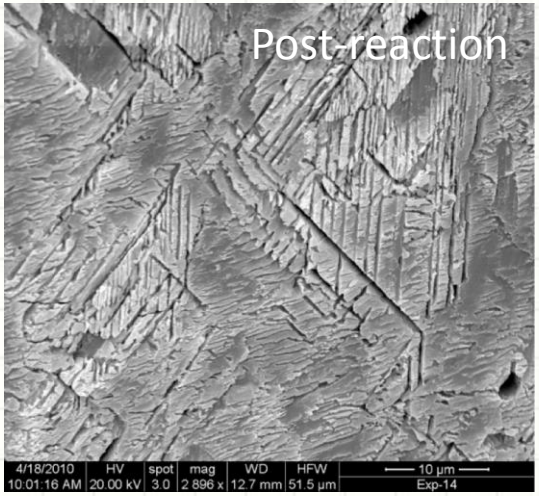
PRECIPITATION/DISSOLUTION

- Goal: Understand Long-term impact of CO_2 injection on mineral dissolution mineralization and control both near the injection and into the formation

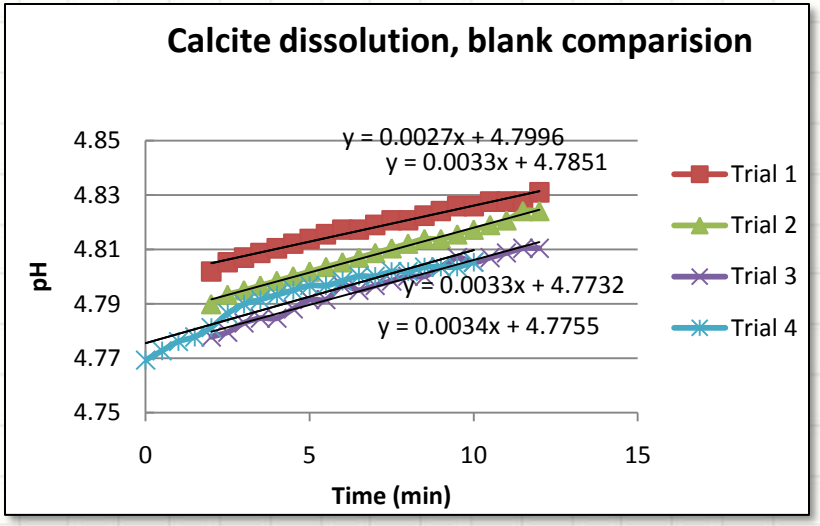
- Study to date
  - Baseline calcite dissolution
  - Effects of additives: phosphonates and surfactants
  - Surfactant desorption experiment
  - Model has been proposed to predict surfactant behavior

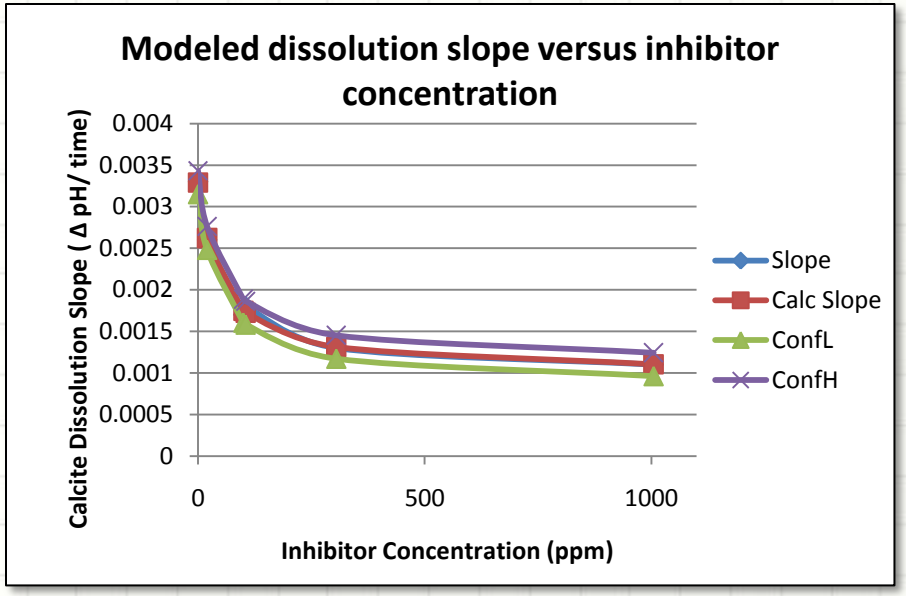


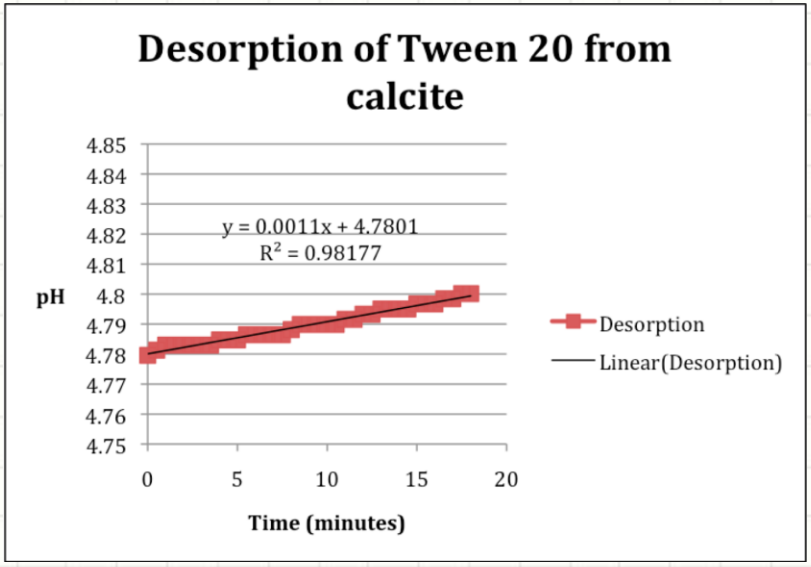




SURFACTANT RESEARCH







- Blank dissolution was established
- Calcite dissolution with surfactant was fitted with a Langmuir type equation
- Desorption from treated calcite is slow for prolonged effectiveness

RICE

PRECIPITATION/DISSOLUTION

- ✓Laboratory simulations of mineral dissolution and precipitation:
  - Near wellbore flow and reaction time
  - Intermediate distances and reaction time, temperature and pressure
  - Long term reaction of CO_2 injections
  - Effects of additives in controlling mineral dissolution and precipitation
  - Mixed ion effects and solid solution
- ✓Mathematical simulation
  - Modeling with Phreeq C, ScaleSoftPitzer, and others

NETL

RICE

SCHEDULE

	Year 1 (2009-10)				Year 2 (2010-11)				Year 3 (2011-12)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1.0 Project Management and Planning												
Task 2.0 Regional Significance												
Subtask 2.1 Geologic Framework												
Subtask 2.2 Capacity and Injectivity Assessment												
Task 3.0 Test Site Characterization												
Subtask 3.1 Site Design and Development												
Subtask 3.2 Injectivity and Capacity												
Subtask 3.3 Geophysical Characterization												
Subtask 3.4 Simulation												
Task 4.0 Containment Analysis												
SubTask 4.1 Stratigraphic Containment												
Subtask 4.2 Dissolution and Mineralization												
Task 5.0 Summary Analysis												
Subtask 5.1 Site Selection Criteria												
Subtask 5.2 Risk Assessment												
Task 6.0 Technology Transfer												

Progress

- ✓Geologic framework
- ✓Assessment underway
- ✓Site selected
- ✓Seismic being permitted
- ✓Simulation tools
- ✓Containment analysis
- ✓Dissolution and mineralization

Coming soon

- Site selection criteria
- Risk assessment
- Best practices manual